NON-TRANSVERSE AEOLIAN RIPPLES ON MARS. S. Silvestro¹, D.A. Vaz²,3, H. Yizhaq⁴ and F. Esposito¹,
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Introduction: Understanding the dynamic of aeolian bedforms is fundamental to reconstruct wind conditions on Mars and to compute important parameters for landscape modification, such as sand flux and erosion rate [1-4]. Of particular interest in ripple's dynamic is the migration of the defects (Y junctions, the termination of one ripple against another) [5]. Computer models and field observations showed that defect migration is fairly normal to the ripple crests and is associated with downwind crestline motion when the flow is unidirectional [5-8]. By using overlapping images over Martian ripples in Herschel Crater, we detected both transverse (Fig. 1) and longitudinal (Figs. 2 and 3) migration of the ripple's Y junctions. As far as we know, this is the first time that longitudinal ripple migration has been observed "in the field".

Methods: Aeolian ripples are studied on HiRISE data (0.25 m/pixel). We used one HiRISE stereo couple to build a DTM with SocetSet [9] and to orthorectify two overlapping images acquired in 2007 and 2010 (T1 and T2). Ripple migration is measured and classified manually by comparing the Y junction migration direction with the ripples crestline trend (see circular plots in Figs. 1-3) [10] and in automatic by deriving the ripple displacement vectors with COSI-Corr [11]. A 3D numerical model of ripple formation is also used to reproduce the observed non-transverse ripple migration [12].

Herschel ripples: Herschel crater is a 304 km impact basin located ~ 700 km SW of Gale, the NASA MSL landing site. It hosts several dune fields shaped by dominant winds coming from the North [13]. Dune's slopes show a large morphological variety of wind ripples [14, 15]. Wind ripples are generally considered transverse to the resultant wind direction so the migration of the defects (Y junction) is perpendicular to the crestline trend (Fig. 1). Ripple migration measured with COSI-Corr also show the downwind (SW) ripple displacement (Fig. 1b). In Fig. 2 we show transverse and longitudinal ripple migration on a longitudinal lee spur located behind a 17 meter-tall barchanoid dune. Here the dune topography is likely deflecting the winds in two different directions toward the SE and the SW. On the spur's sides ripples are mostly transverse while where the two flows converge longitudinal ripple migration is observed (Figs. 2a, 2b). These longitudinal ripples can be morphodynamically similar to the ones obtained experimentally by [16]. In Fig. 3a we show active ripples trending N-S located directly downwind of a set of 0.4-0.6 meters-tall TARs. By looking at the T1 and T2 images we noticed that individual ripples are not migrating toward the East/West as expected. Instead, they elongate downwind with the Y junction being displaced towards the south. The inactive TARs are probably too small to create lee flow convergence (Fig. 2) so the active ripples were likely formed by E/W winds funneled between the TAR crests. Then, the wind changed and ripples have been reworked by the dominant winds from the N that pushed the Y junctions toward the S. This is shown in

Fig.1: Transverse ripples. a) T1 ripples moved toward the SW at T2. Black arrows represent the direction of motion of the Y junctions which are plotted against the ripple trend in the circular plot. b) COSI-Corr migration direction and magnitude.
a 3D mathematical model [12] of normal ripples based on Anderson’s idea [17] that ripples develop due to spatial differences in the reptation flux and that the role of saltation is merely to introduce energy into the system. The model shows the Y junctions migrating along the ripple crest when an along-crest wind (left to right) is modeled (Figs. 3b-d). Alternatively, the active dark ripples might be similar to streamwise spurs [18] (see also [15]).

Mars transient ripples might be more insensitive to wind changes because ripples are bigger (1 meter or more in wavelength against 10 cm for terrestrial ripples) and winds sufficiently strong to reorient ripples are more infrequent relative to those on Earth. This is consistent with the complex ripple orientation observed in Gale [3] and Meridiani [19]. Collectively, our observations suggest that the assumption of the transverse nature of ripples must be used with caution on Mars. In addition, sand flux measurements derived from ripple migration rates [4] might be underestimated in areas where longitudinal ripple migrations occur.


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Discussion: The data presented in this report clearly show non-transverse ripple migration on Mars. Two main flow configurations are hypothesized to explain the observed longitudinal ripples: a) flow convergence with two winds approaching obliquely the ripple crest (Fig. 2) b) bedforms emplaced by transverse wind and subsequently reworked by flows blowing parallel to the ripple crests (Fig. 3). Because ripples tend to quickly adjust transversely to the last wind, the observed longitudinal Martian forms are likely transient. On

![Fig.2: Transverse and longitudinal ripple migration. a) Manual mapping b) COSI-Corr displacement vectors.](image)

![Fig. 3: Observed a) and modeled b-d) longitudinal ripple migration assuming a 90° rotation of the winds. The white arrows show the downwind (left to right) displacement of the Y junction.](image)